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An Evaluation of Pedestrian Bus Stop Accessibility Through the Existing Sidewalk Network in Austin, Texas

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An Evaluation of Pedestrian Bus Stop Accessibility Through the Existing Sidewalk Network in Austin, Texas

by

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Dedication

The completion of this report symbolizes the achievement of a life-long dream – not only mine but of my parents. It is difficult to grasp the challenges they have overcome and the sacrifices they have made for me to finish this level of education. It is thanks to their support that I have gotten to this point. For these reasons I dedicate this work to them.

Acknowledgements

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Abstract

An Evaluation of Pedestrian Bus Stop Accessibility Through the Existing Sidewalk Network in Austin, Texas

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The University of Texas at Austin, 2020

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This study explores neighborhood bus stop accessibility through the currently existing sidewalk network in Austin, Texas. The main methodology for this analysis involves the use of GIS Network Analyst. This topic is important for the City of Austin because it is currently missing a significant portion of their sidewalk network yet sidewalks provide an essential part of mobility infrastructure, especially for access to public transit. The use of public transit is becoming increasingly important in order to address sustainability, health, and transportation issues that are almost universally found across large urban areas. The GIS based approach used in this study focuses on residential building accessibility from bus stops across the City of Austin. Results show that the best-connected neighborhoods are not the ones with the most complete sidewalk networks. Instead, the availability of bus stops in the neighborhood is what was most associated with neighborhood connectivity. Results also show enormous increases in residential building accessibility to bus stops through a full build out of sidewalks found at 5, 10, and 15 minute pedestrian service areas.

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INTRODUCTION

This study explores neighborhood bus stop accessibility through the currently existing sidewalk network in Austin, Texas. The main methodology for this analysis involves the use of GIS Network Analyst. This topic is important for the City of Austin because it is currently missing a significant portion of their sidewalk network yet sidewalks provide an essential part of mobility infrastructure, especially for access to public transit. Most transit trips begin and end as pedestrian trips and so it becomes essential to have a fully-functional and continuous sidewalk system to use to reach transit stops. City residents are able to use a well-connected, well-maintained sidewalk network to walk in a designated pedestrian space which is safe and comfortable. As per the American Public Transportation Association, public transportation systems provide 9.95 billion unlinked passenger trips per year, saving the United States 4.16 billion gallons of gasoline (APTA 2020). Public transportation has grown by 37% since the 1970's (APTA 2020). CapMetro reports that it boards 31.8 million passengers per year, a substantial number of trips that are taken using transit (CapMetro, 2020). The existence of a connected sidewalk network makes alternative transportation options, such as riding transit, more attractive for all city residents.

It becomes especially important to consider improvements to the sidewalk network in Austin as the city is one of the fastest growing in the United States. In 2019, the typical City of Austin commuter experienced 69 hours of driving in congested conditions, a cost of $1,021 per driver (INRIX 2019). Prominent transportation modes, such as using private vehicles, will increasingly become more cumbersome as the majority of city residents use the roads. As the city population grows, transportation related emissions will also increase. Adopting greater walking and transit use in the city's overarching transportation modes can serve to reduce emissions and help reach the city's long-term sustainability and health goals.

There is large variability in the accessibility that Austin neighborhoods experience when it comes to sidewalk network completeness. Neighborhoods within the City of Austin have differing levels of existing and missing sidewalks. Whereas some parts of the city have nearly-complete sidewalk networks, others have almost none. On top of this, existing sidewalks are theoretically fully functional and fully accessible but can lack the maintenance that allow uninterrupted sidewalk use. For example, vegetation can block the sidewalk path, or part of the sidewalk may have large cracks and ridges that makes it difficult to walk on. This report takes this fact into consideration when analyzing pedestrian accessibility to bus stops.

The City of Austin's public transportation system, CapMetro, runs three types of bus routes. MetroBus is the local, frequent stop service that operates throughout the city. MetroRapid operates two lines which are high frequency and limited stop service. MetroExpress serve areas outside the city of Austin such as Manor and Elgin. All bus stops from these three CapMetro bus route types were used in this study's analysis.

Research Questions

1. Are there any bus stops in Austin that are inaccessible due to a lack of sidewalk infrastructure?
2. What Austin neighborhoods experience the best and worst connectivity to bus stops?

Research methods and plan of the work

The research methods for this report will be conducted in two parts. The first will include a literature review, which will provide context for the planning efforts related to sidewalks in the City of Austin. The literature review will highlight past study results which demonstrate the effectiveness of sidewalks as a connector to public transportation. The second part of the research for this report will be done through a GIS analysis of the current state of Austin's sidewalk network. The City of Austin was chosen as the site location for this report because of the general knowledge that the city is not the most pedestrian friendly when it comes to sidewalks. The city of Austin is also one of the fastest growing cities in the United States; the city has been facing and will continue to face transportation related issues as the city population continues to grow. While this report was being written, the City of Austin passed a 10-billion-dollar public transportation plan - Project Connect – which will, in part, rely on heavier use of buses (Jankowski, 2020). Austin has unique urban forces that make it a prime location to conduct bus stop connectivity analysis at the neighborhood level.

In this report's literature review, we will explore the benefits of public transportation systems and of sidewalk connectivity. We will then contextualize these benefits and explain the City of Austin's current goals regarding sidewalks and public transportation systems. The methodology for this report will be laid out, and will be followed by results and discussion.

LITERATURE REVIEW

The reason that this study aims to observe neighborhood connectivity to bus stops is because of the benefits that the bus system confers. Bus systems provide transportation services for all people, whether it is young students heading to class, families on their way to the grocery store, or individuals heading to work. Bus networks also allow individuals to access a variety of destinations even if they do not own a personal vehicle, or if a destination is too far to walk or bike. The bus system helps people with physical disabilities with mobility. The bus system is a required part of the transportation network across any city. However, in order to use a transit system people usually need to walk, which can be difficult in car-centric cities. Communities are designed in a car centric manner (Lavizzo-Mourey and McGinnis, 2003) and as a result, most people use motorized transportation for daily tasks such as going to work and running errands (US Department of Health and Human Services, 1996). The current predominance of using private automobiles for transportation comes with other negative externalities as well. Transportation issues in developed countries include traffic congestion, single-occupant automobile travel, pollution, and increasing infrastructure costs (Badland and Schofield 2005). Since most transportation occurs through vehicle transportation, there is much room to increase active transportation rates.

There are negative health outcomes from depending on private vehicles as the main method for transportation. The dependence of personal vehicles for transportation reduces the amount of physical activity that would could have been carried out through other forms of transportation. Physical inactivity is one of the leading causes of diseases such as cardiovascular diseases, type 2 diabetes, and some cancers (World Health Organization, 2004). These diseases place a large economic burden and so are a great cost to society by causing disruptions to economic growth and development (World Health Organization, 2004). Many countries are experiencing low physical activity level and increased obesity rates (World Health Organization, 2004). Physical inactivity is bad for health yet even small amounts of activity provides positive health benefits (US Department of Health and Human Services, 1996).

WHO recommends the following interventions for the prevention of health risks attributable to physical inactivity: "Introduction of transport and environmental policies that promote physical activity", and "encourage environmental planning that allows increased walking, cycling, and other physical activities" (World Health Organization, 2004). This shows that the intersection of health promotion, transportation, and urban design policies are trying to achieve the same thing – to provide solutions that can be applied to the mass quantity of people (Badland and Schofield 2005). This also shows that negative externalities stemming from vehicle use and physical inactivity can be partially solved through transportation planning.

One way to increase physical activity as per WHO suggestions is by improving the sidewalk network. Sidewalks encourage people to be physically active (Landis et al., 2005). The availability of sidewalks corresponds with the improved use of active transport. Walking to transit increases physical activity levels which is essential in improving health and fighting against diseases related to a sedentary lifestyle (Wasfi et al., 2013). The recommended minimum amount of physical activity of 30 minutes per day can be achieved by walking to transit stops (Wasfi et al., 2013) and transportation mode shifts to non-motorized forms of transportation lead to better health outcomes through an increase of physical activity (Woodcock et al., 2009).

The built environment has a significant influence in choosing non-auto modal decisions (Woldeamanuel 2015). Cervero and Kockelman's research has shown that modal decision making is influenced by the built environment (1997). Cervero's analysis of built analysis factors that encouraged walking to transit stops determined that sidewalk availability was important (1997). The presence of sidewalks is considered encouraging when people choose a commuting route (Guo, 2009). Guo finds that the presence of sidewalks contributes to the choice to walk (2009). The built environment has an influence on the appeal of physical activity by providing accessible, safe, and convenient space for physical activity (King et al., 1995).

Alternatively, it is possible that the "unavailability, low-quality, and disconnectedness" of sidewalks discourages the use of public transit (Woldeamanuel 2015). The presence and quality of sidewalks is attributable to pedestrian perceived safety (Landis et al., 2005).

Rodriguez and Joo (2004) studied the effects of the local physical environment on non-motorized travel mode choice. Topography, sidewalk availability, residential density, and presence of cycling and walking paths were used to model the environmental attributes with mode choice. They found that sidewalk availability is highly associated with attraction of alternative, non-motorized modes (Rodriguez 2004).

Woldeamanuel and Kent (2015) created a Sidewalk Availability and Quality Index (SAQI) to calculate access to transit stops. Using a regression, they found a positive relationship between the index and the use of public transportation. This suggests that quality and connectivity of sidewalks impacts transit use. A lack of sidewalk infrastructure and disconnected street eliminates transit as a transportation mode for many because of a lack of access (Woldeamanuel 2015). In Woldeamanuel's results, they found that transit ridership increases as sidewalk quality and connectivity improves (2015).

Additionally, the presence of sidewalks is associated with the reduction of driving (Marshall and Garrick, 2010). Studies done on highly walkable neighborhoods report a higher rate of walking as a transportation mode choice. Attributes of highly walkable neighborhoods include a highly connected pedestrian network, strong access to sidewalks, and high numbers of bus stops (McCormack et al., 2012). Residents of highly walkable neighborhoods are also more likely to walk for transportation within their own neighborhoods (McCormack et al., 2012).

Small physical modifications that encourage physical activity lead to small individual changes which can accumulate to larger societal benefits. These societal benefits include healthcare expenditure reductions, traffic congestion reduction, pollution reduction, and infrastructure cost reduction (Badland and Schofield 2005). Greenhouse gas emissions and air pollutants can be reduced by transitioning from private vehicle usage to transportation modes such as public transportation and walking (Watts et al., 2018). A move away from private vehicle use reduces emissions from vehicles and reduces air pollution (Watts et al., 2018)

Bus travel increases transportation options and more notably supports a sustainable form of travel. Importantly, it supports the health of nearby residents. Even then, the success of a bus system depends on the walkability of the adjacent neighborhoods. Neighborhood walkability creates convenient and safe access to a bus stop (Vale 2015).

Health outcomes in Austin could be improved by promoting transit use through improvements to the built environment, such as sidewalks. By examining Austin neighborhoods, we attempt to see which neighborhoods could improve the most by improving transit access. Those that are missing large percentages of sidewalk could stand to gain the most from an improved built environment. Walking is an essential part of mobility: it is available to almost everyone, and it is the most preferred form of physical activity for the general population (Badland and Schofield 2005) and sidewalks provide the main areas for walking (Landis et al., 2005). Sidewalks provide an essential service for the functionality and equity of transport systems such as bus networks (Landis et al., 2005). People are able to access not only bus services but health facilities, parks, retail, and schools through a well-connected, well-maintained sidewalk network (Landis et al., 2005).

This study compliments the existing studies by examining three sidewalk-related attributes: percentage of missing sidewalk, density of bus stops, and residential accessibility from bus stop locations. GIS has been used in past studies to model neighborhood physical activity levels (Badland and Schofield 2005); although there is a lot of analysis of sidewalks done at the street level, there is not a lot done at the neighborhood level (Aghaabbasi 2017). Although this study does not seek to find a relationship between the physical environment and bus stops, it helps to understand the experience of pedestrians who use the transit system in Austin. This in turn may help may help make practical decisions for future sidewalk construction and prioritization.

Austin and Sidewalk Planning

The City of Austin Transportation Department (ATD) and the City of Austin Public works are the two main agencies that plan for active transportation infrastructure such as sidewalks. Several policy documents exist that pertain to the planning and construction of sidewalks in the City of Austin. These include Austin's comprehensive plan, Imagine Austin. Other documents include the Austin Strategic Mobility Plan (ASMP), and the City of Austin Sidewalk Master Plan. In addition to these documents, the City of Austin has also implemented initiatives such as Vision Zero, which aims to "end traffic related fatalities and serious injuries, while increasing, safe, healthy, and equitable mobility for all" (Vision Zero 2019).

The Imagine Austin Comprehensive Plan was adopted in 2012, and lays out the framework to Austin's future growth. Sustainability is Imagine Austin's central policy and is defined as: "considering not only the needs of today, but also whether these needs are being met in ways that conserve resources for future generations. Sustainability means finding a balance among three sets of goals: 1) prosperity and jobs 2) conservation and the environment, and 3) community health, equity, and cultural vitality. It means taking positive, proactive steps to protect quality of life now and for future generations." (Imagine Austin Comprehensive Plan 2018, pg 7)

There are eight priority programs in Imagine Austin. The priority programs were ranked by the general community; the top-ranking priority program is "investing in our transportation system to create a compact and connected Austin" (Imagine Austin Comprehensive Plan 2018). Goals for this priority program include increasing non-vehicular trips and improving access to transit (Imagine Austin Comprehensive Plan 2018).

The Austin Strategic Mobility Plan (ASMP) was approved by Austin city council in 2019 and is the first local transportation plan to incorporate all transportation modes in a plan (2019). The ASMP recognizes the importance of the sidewalk system and includes policies and goals for Austin's sidewalks, as well as implementation methods needed to realize these visions. The goals set by the ASMP for Austin's sidewalks include

- Achieving and maintaining 95% functionality for Austin's high priority sidewalks by 2026
- Achieving and maintaining 55% functionality for Austin's sidewalks overall by 2026
- Build 100% of missing high-priority sidewalks within a quarter mile of transit stops by 2026
- Improve access to public transportation

Policies for Austin's sidewalk system include:

- Complete the sidewalk system
- Make the sidewalk system accessible and comfortable for all
- Maintain the usability of the sidewalk system
- Ensure new development connects to the sidewalk system

Implementation methods for Austin's sidewalk system include:

- Updating the land development code
- Working with council members
- Various sidewalk programs
- Improving sidewalk functionality through vegetation removal

The ASMP outlines the need and the difficulties associated with the construction of and maintenance of the sidewalk system while addressing a general plan to achieve the goals specified above (2019). However, this plan is a general transportation plan for the City of Austin. The City of Austin has a City of Austin Sidewalk Master Plan which largely revolves around the prioritization of sidewalk construction.

The latest City of Austin Sidewalk Master plan was adopted in 2016, and responds to City goals of encouraging walking as a viable mode of transportation, enabling people to walk to and from transit stops, improving mobility for people with disabilities, and controlling air pollution and air congestion (City of Austin Sidewalk Master Plan, 2016). The master plan lays out recommendations for maintaining existing sidewalks and for the construction of new sidewalks. Based on the miles of missing sidewalk in 2015 (2,580 miles), the City of Austin estimates a cost of 1.64 billion dollars to construct all missing sidewalk. The 2016 budget for new sidewalk construction was $8,600,00. A full build out of the sidewalk network would take 192 years to complete with 2016 budget levels. This is a very long amount of time, so an index has been created to facilitate sidewalk construction. A selection of sidewalks has been prioritized for construction within the next 10 years. This selection consists of sidewalks that are ranked “high” or “very high” priority which are within a ¼ mile of schools, bus stops, and parks. This amounts to 390 miles of new sidewalk in 10 years (City of Austin Sidewalk Master Plan, 2016).

The City of Austin has created initiatives such as Vision Zero, which aims to “end traffic related fatalities and serious injuries, while increasing, safe, healthy, and equitable mobility for all” (Vision Zero, 2019) Vision Zero view traffic related fatalities in the perspective of a public health issue. Vision Zero was adopted by City council in October of 2015 as a policy within Austin’s comprehensive plan, Imagine Austin. Vision Zero is led by the Austin Transportation Department, who partners with other “City departments, state and federal agencies, and community organizations to implement traffic safety efforts citywide” (Vision Zero, 2019). Partners include Capital Metro. As a part of Vision Zero, leading pedestrian intervals (LPI) provide pedestrians a few seconds head start for crossing an intersection before drivers are allowed to go. This program improves pedestrian safety and so improves the pedestrian experience in Austin.

The City of Austin has laid out several documents and programs that demonstrate the effort that is being placed into improving pedestrian infrastructure, which will in turn help the city accomplish goals in its comprehensive plan. The City is aware of the challenges faced by the current sidewalk system and the benefits sidewalk infrastructure can confer. It is also apparent that Austin intends its sidewalk network to play a large role in its overall transportation system. This report evaluates neighborhood accessibility to bus stops using the current sidewalk network and so helps the City of Austin move towards their mobility goals.

METHODOLOGY

This study attempts to analyze pedestrian accessibility to all bus stops found within the City of Austin boundary. The City of Austin was chosen as the study area because (1) it is where the researcher is located; (2) the availability of rich and up-to-date GIS data for analysis; (3) the researcher would like to make this document something that is helpful to the City of Austin.

Study area and the Unit of Analysis

This study uses three geographic levels for analysis. The first level is the city-wide level, used to obtain a large-scale understanding of the study area. The neighborhood level is the second geography used for analysis. The City of Austin boundary is composed of one hundred and three neighborhoods. Neighborhoods are chosen as the spatial level for analysis because the geography is meaningful to city residents and to the City of Austin. It is more meaningful to make observations on a specific neighborhood than a specific census tract, for example. Neighborhoods included in the City of Austin's Neighborhood Reporting Areas are used as the geographic boundaries in this report. The bus stop level is the third unit of analysis. The bus stop is used as a level of analysis to obtain a detailed look at the sidewalk network immediately adjacent to CapMetro bus stops.

Data Preparation

The Neighborhood Reporting Areas GIS layer was provided by City of Austin staff. This data provides boundaries for the 103 neighborhoods found in the COA. Although the City Of Austin's Open Data Portal provides data on Neighborhood Planning Areas, the data includes only 65 neighborhoods. The Neighborhood Planning Areas dataset only includes neighborhoods with an adopted neighborhood plan. The Neighborhood Planning Area layer was not used in this report as the Neighborhood Reporting Areas layer is more comprehensive.

The sidewalks layer used for this study was obtained from the City of Austin's Open Data Portal. The City of Austin maintains this sidewalk dataset continuously; the most up-to-date dataset was used for this project. The dataset is a GIS layer with attributes that categorize sections of sidewalk as "existing", "missing", or "driveway". Sidewalk GIS data from this source is comprehensive for the City of Austin and so serves as the best source for sidewalks data.

It is important to note that no data is included on the state of maintenance of existing sidewalk sections within the aforementioned sidewalk layer. However, the City of Austin collects separate "Sidewalk Conditions" data which was included in this study. The Sidewalk Conditions data was obtained from the Open Data Portal. Sidewalk sections in this dataset are marked as "functionally acceptable" or "functionally deficient". The City of Austin has collected this data for 22.8% of existing sidewalks so it must be noted that this data is not exhaustive. The Sidewalk Conditions dataset was used to refine the sidewalk layer. Sidewalk sections labeled as "functionally deficient" were considered missing sidewalks because they disrupt continuity and quality of the existing sidewalk network. Sidewalks Conditions data are taken into consideration when the data is available.

The sidewalk data was separated into two layers, seen in Figure 1. One layer was created for existing sidewalks and another for missing sidewalks. The existing sidewalks layer is constructed of: existing sidewalks that are in functionally acceptable condition, and driveways that are in functionally acceptable condition. The missing sidewalks layer is constructed of: missing sidewalks, existing sidewalk that are in functionally deficient condition, and driveways in functionally deficient condition. The two layers are separated in this manner in order to obtain an accurate representation of the real-life sidewalk system as possible. The existing sidewalks layer is used to create the network upon which this study is conducted and is therefore the foundation for this analysis.

Something that is vital to note is that the City of Austin's sidewalk layer lacks connectivity across blocks, neighborhoods, etc. This can be seen in Figure 1. Crosswalks are not included in the data. Blocks are not connected to one another. This presents a challenge because connectivity is necessary to model pedestrian activity in ArcGIS. A network was not buildable using the existing sidewalk layer due to a lack of connectivity in the layer.

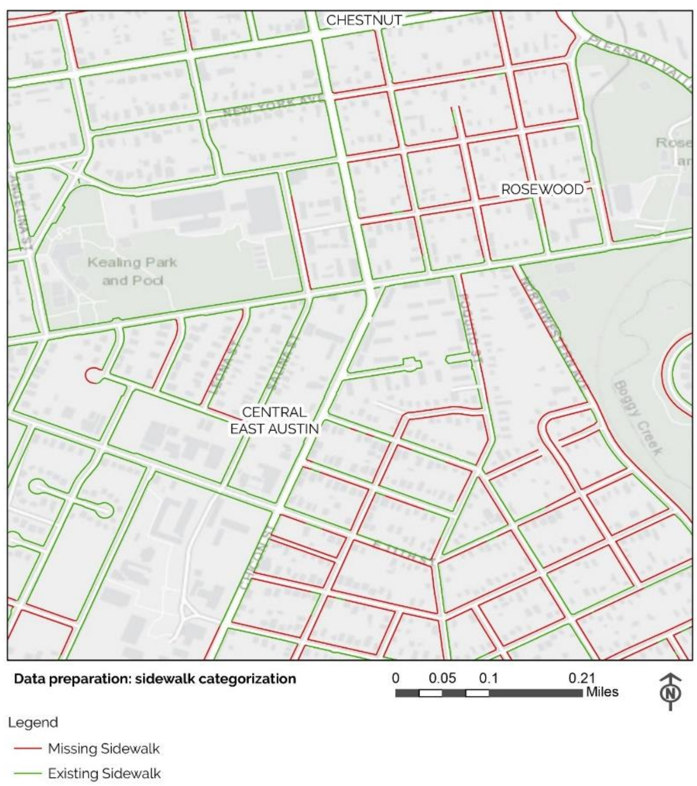

Figure 1: Preparing the Sidewalk Layers

A solution to this issue came in this manner: a roads layer was used to represent the existing sidewalks. North America Detailed Streets (NADS) data represents detailed streets, interstate highways, and major roads located in the United States. NADS data contains the proper connectivity needed to create a Network Dataset in ArcGIS.

A 70-foot buffer was created around existing sidewalks and was used to clip the NADS data. The result is a roads layer that resembles the existing sidewalks in the City of Austin and provides the connectivity needed for GIS analysis. A buffer distance of 70 feet was chosen for clipping because it is the shortest distance possible to capture road intersections, which are needed for the creation of a Network Dataset. The creation of a Network Dataset would not be possible without maintaining this connectivity. A distance shorter than this would more accurately depict the existing sidewalks layer but would lose the connectivity needed to create a network.

The next essential piece for this report is CapMetro bus stops data. CapMetro is Austin's public transportation system. Their GIS data is publicly available through the CapMetro website. CapMetro GIS stops data were obtained through their website. The bus stops serve as the points from which walking service areas are created in GIS, a process which is detailed in the next section.

City of Austin building footprints are another important piece for this report, which uses bus stop accessibility to residential buildings as a measure of bus stop connectivity. Building footprints for the City of Austin are obtained from the city's Open Data Portal and are the most updated footprints available as of June 2020. Courtyards and buildings smaller than 350 square feet were removed from the footprints data. The 350 sq. ft threshold was employed to remove footprints that are too small to be residences, yet maintain Additional Dwelling Units in the footprint data. The COA building footprints data did not include land use or zoning information. To acquire this information for the building footprints in Austin, land use data at the parcel level was obtained from Austin's Open Data Portal and was then spatially joined with the footprints. After the spatial join was conducted, the footprints with residential land uses were extracted to represent all residences in the study area. Residential footprints are defined as structures with any of the following land use descriptions: Apartments, an assortment of condo types, mobile homes, single family homes, and large lot single family homes. Mixed use was included as residential when its land use incorporated apartments, condos of any variety, or one-family dwellings. Residential footprints are used to measure levels of bus stop connectivity because residences are often the starting point from which a transit trip originates, and because the report aims to observe neighborhood connectivity to bus stops.

Analysis Approach

The clipped road data, representative of the existing usable sidewalk network in Austin, was used to create a pedestrian Network Dataset using Network Analyst in ArcGIS. The bus stops found within the COA boundary were imported into the Network Dataset as facilities with a 70 ft location tolerance. A 70-foot location tolerance was used in an attempt to accurately measure the number of stops that connect to existing sidewalks. Service areas were created for all bus stops found within the City of Austin boundary. Service areas were generated for 5-minute, 10-minute and 15-minute walk times (Figure 1). A walking speed of 2.5 miles per hour was used to calculate walking service areas. The resulting service areas were used to calculate the number of residential building accessible within 5, 10, and 15-minute walking times. A second set of walking service areas were created using a "full sidewalk" scenario. The full sidewalk scenario assumes the full build out of the sidewalk network and so uses a pedestrian network dataset that mirrors a complete sidewalk network. The full sidewalk scenario serves to compare between current sidewalks and a complete sidewalk scenario. TransCAD overlays were used to obtain neighborhood-level analysis. Included in the overlay results are total sidewalk miles per neighborhood, total miles of missing sidewalk per neighborhood, total number of bus stops per neighborhood, and other measures. A TransCAD tag operation was used to obtain sidewalk conditions surrounding bus stops.

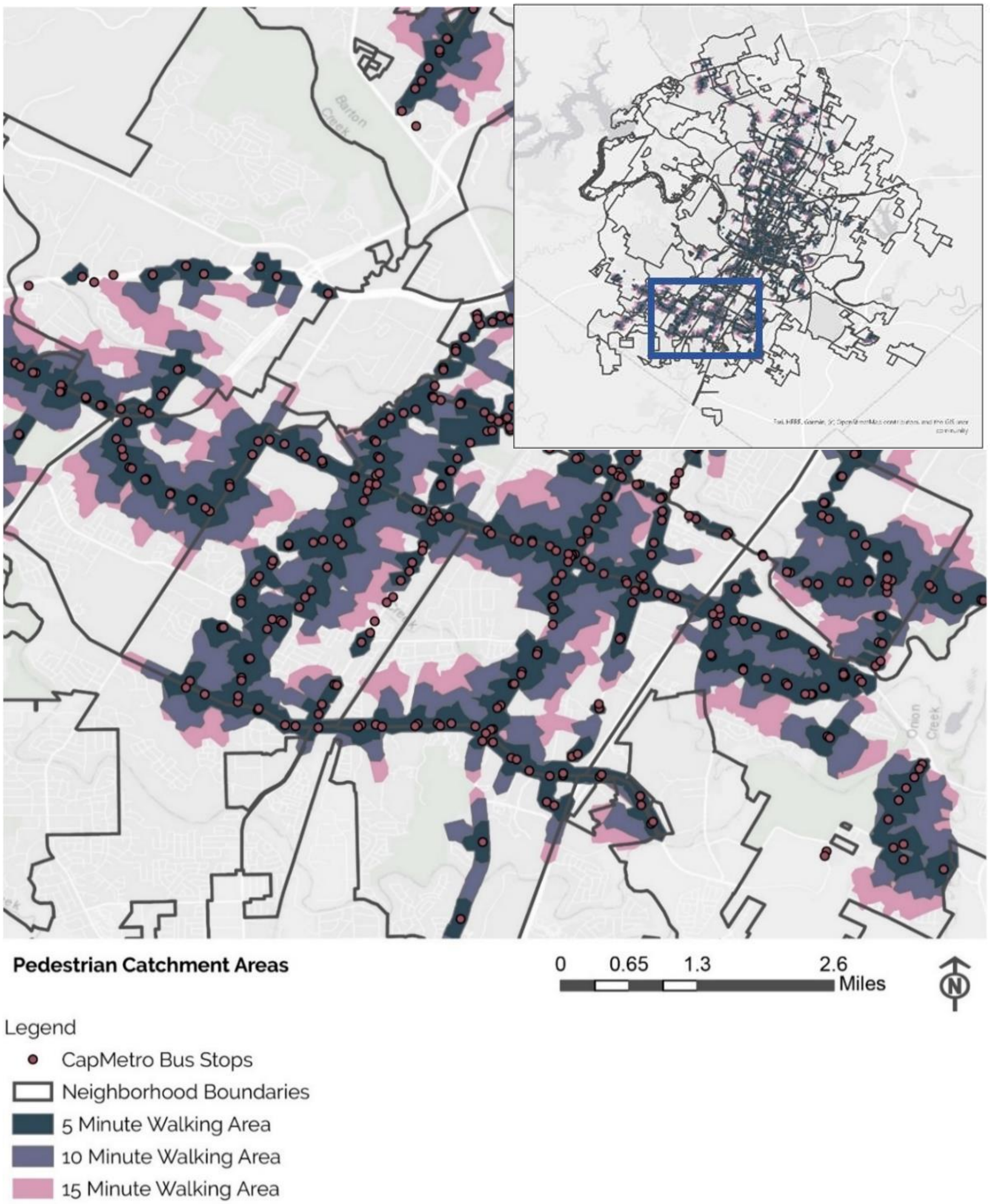

Figure 2: Pedestrian service areas

RESULTS AND DISCUSSION

Results have been separated into three tiers. The three tiers designate analysis at a different spatial scale. The first tier includes analysis at the city-wide scale. The second tier looks at analysis at the neighborhood level. The third tier looks at the bus stop level for analysis.

City-Level Results

Tier one results will focus on analysis at the city-wide scale. It is meant to provide a high-level view of the current state of the sidewalk network by using general spatial patterns of sidewalks and bus stops, and will use agglomerated residential accessibility numbers as an indicator of the performance of the sidewalk network.

A total of 2,271 miles of sidewalk currently exist in the study found in the City of Austin. There are 2,290 miles of sidewalk that still need to be constructed (Figure 2). A total of 46% of the sidewalk network in the study area is missing. Out of the 2,271 existing miles of sidewalk, 386 miles (17%) are considered functionally deficient, although it is important to note that the data on sidewalk functionality only covers 22.8% of existing sidewalk. If functionally deficient sidewalk is considered absent, then 58% of Austin's sidewalk network is missing.

At the city level, both existing and absent sidewalk are widespread across the study area. No spatial pattern exists. Existing sidewalks, as well as absent pieces of the sidewalk network, are found across the entire study area.

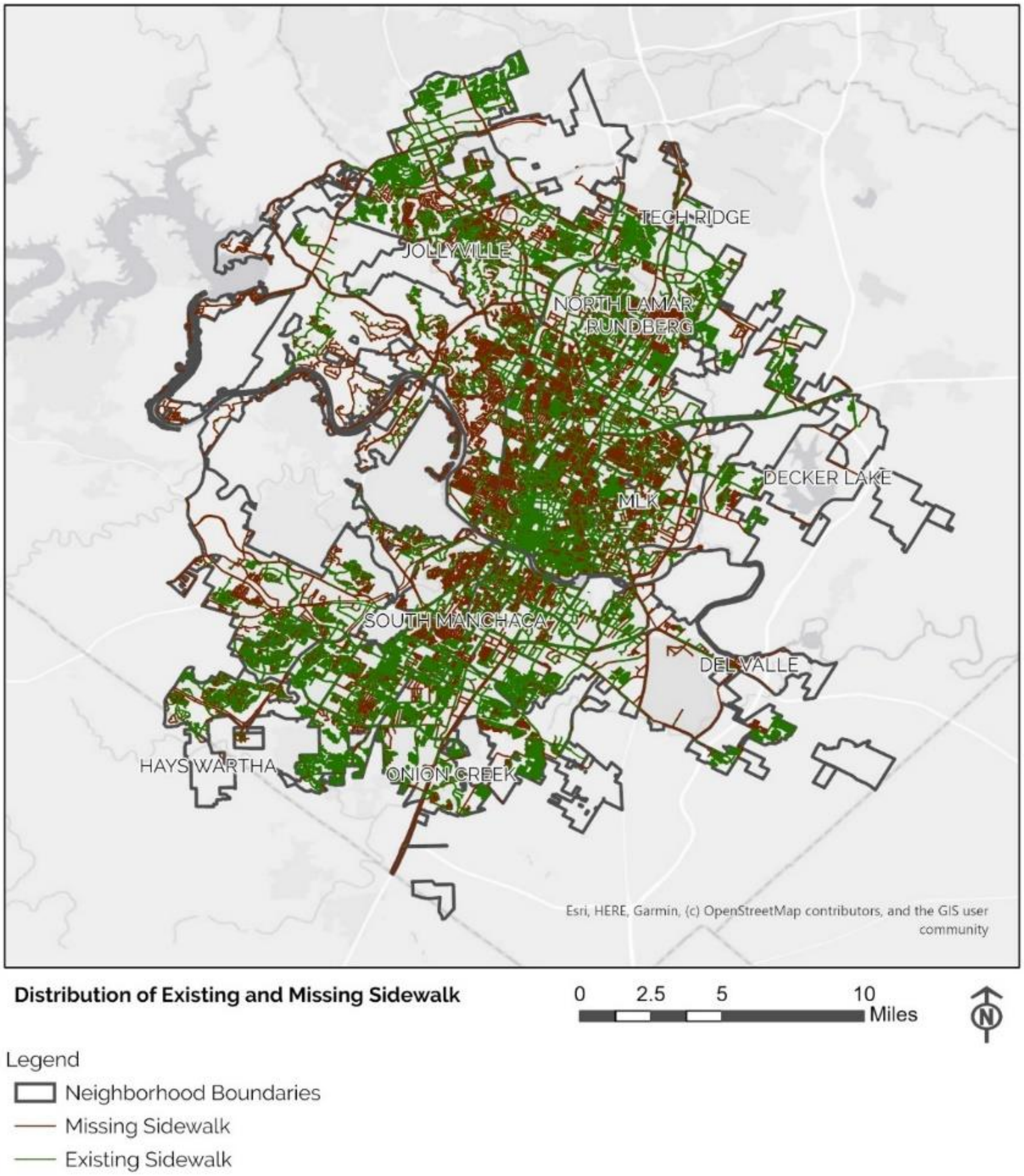

Figure 3: Distribution of Existing and Missing Sidewalks

A total of 2,274 bus stops are found within the 103-neighborhood area. Figure 3 shows the distribution of CapMetro bus stops across the study area. Bus stop densities vary across the study area. Downtown Austin sees the highest density of bus stops, while the study outskirts see the least density of bus stops. Stops are found throughout the area of study.

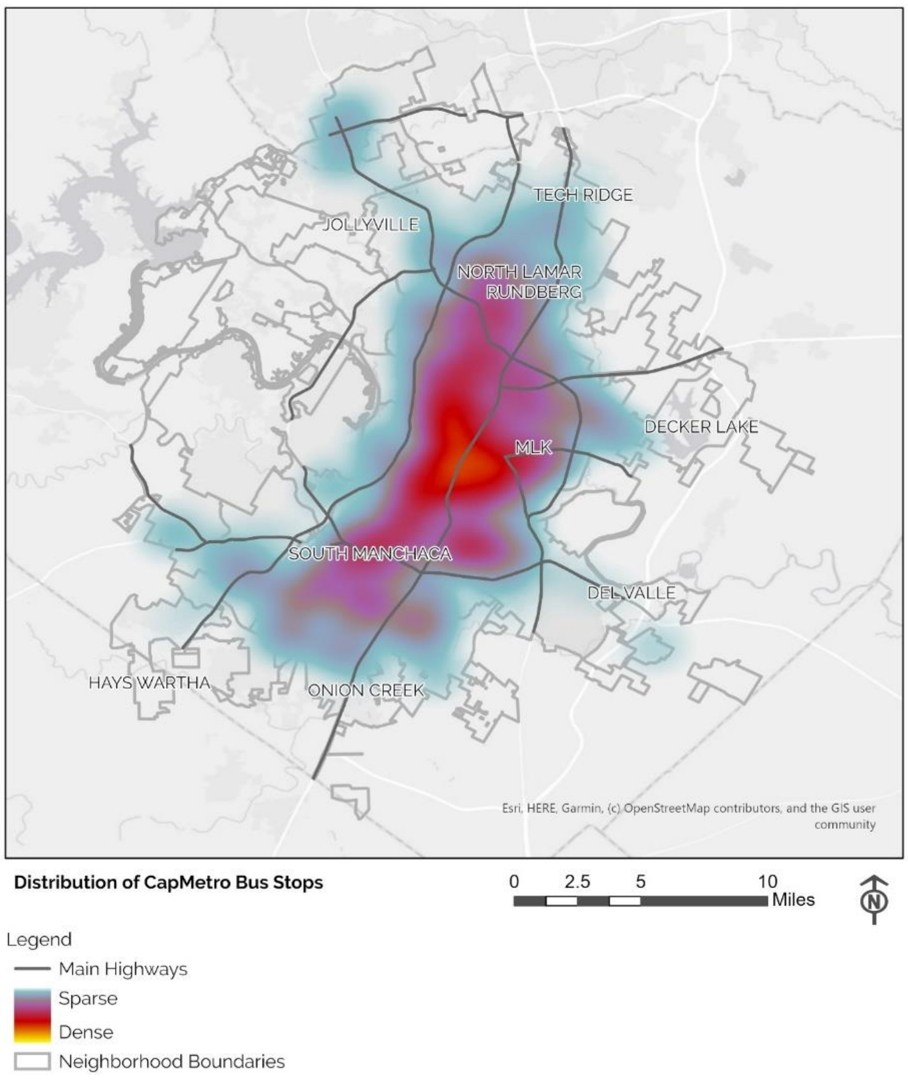

Figure 4: CapMetro Bus Stop Heat Map

A total of 210,439 residential buildings were found within the City of Austin. Table 1 shows the total number of residences accessible within 5-minute, 10-minute, and 15-minute walking times from all bus stops found in our study area. These counts reflect the number of residences accessible while exclusively using Austin's existing sidewalk network. Twenty five percent of all residences in the City of Austin are within a minute walking distance of a CapMetro bus stop. The percentage of accessible residences increases the longer the walking time: 40% of residences are within a 10-minute walk from a bus stop and 47% are accessible within a 15-minute walk. A total of 210,439 residential buildings were found in the study area. The total number of residential units was not calculated.

	Number of accessible residential buildings	Percent of residential buildings accessible
5 Minute Walking Distance	52,491	25%
10 Minute Walking Distance	83,560	40%
15 Minute Walking Distance	99,692	47%

Table 1: Number of accessible residential buildings found within various walking distances

Table 2 details the number and type of residences accessible within the three walking times. Land use data includes the following for residential land uses: Apartments/Condos, Large Lot Single Family, Mixed Use, Mobile Homes, and Single Family. Of the 210,439 residential buildings found in the study area, 9.4% are Apartments/Condos (19,759 buildings), 0.1% are Large Lot Single Family (145 buildings), 0.1% are Mixed Use (132 buildings), 2.2% are Mobile Homes (4,558 buildings), and 88.3% are Single Family (185,458 buildings).

The majority of mixed-use residential buildings are accessible within 5 minutes of a bus stop – 86% - suggesting that mixed use residential buildings are well placed along bus stop routes or that bus stops provide good service to this residential type. Interestingly, the percent of mixed-use residential structures does not drastically increase past the 5-minute walking point. At 15 minutes of walking distance, 89% of mixed-use residences are accessible.

In contrast, only 1% of large lot single family homes are within a 5-minute walk from a bus stop – the lowest of any category of housing. This might be because of the location of the large lot single family homes. They may be found in areas where there is no bus service or they may be found in areas with really poor sidewalk connectivity. The larger lot size may just be a physical inhibitor of accessibility where longer walk times are necessary to reach the homes. At the 15-minute walking time, large lot single family homes still hold the lowest accessibility to bus stops of all residential categories at 8% accessible.

		Measure of residence type within 5 minutes of a bus stop		Measure of residence type within 10 minutes of a bus stop		Measure of residence type within 15 minutes of a bus stop	
Residence Type	All COA	Total	Percent	Total	Percent	Total	Percent
Apartments	19,759	6,678	34%	8,419	43%	9,285	47%
Large Lot Single Family	145	2	1%	5	3%	12	8%
Mixed Use	132	114	86%	114	86%	117	89%
Mobile Home	4,558	714	16%	1,154	25%	1,402	31%
Single Family	185,845	44,983	24%	73,868	40%	88,876	48%

Table 2: Residences found within various walking distances from bus stops

By comparing accessibility across residential types, patterns can be observed in bus service equity. For example, it is a great thing that 86% of mixed-use residential structures are within a five-minute walking distance of a bus stop, but apartments and mobile homes, which can be more financially accessible, experience a much lower share of structures within the same walk time. Future studies may look into income levels, race, gender, educational levels across the city of Austin to look at the equity of the bus system. For now, what is observable is that some residential structures in Austin have better accessibility and connectivity through the existing sidewalk network than others.

As previously mentioned, a second sidewalk network was modeled using ArcGIS. The second sidewalk network used a fully connected, functionally acceptable sidewalk network to observe pedestrian accessibility to residential structures. The same data was used – same residential structures, same bus stops. The only thing that changed was the sidewalk network. A comparison in residential accessibility between the same walk times is shown in Table 3.

Accessible residences for each sidewalk network – City of Austin			
	Existing Sidewalks	Full Sidewalks	Percent Difference
5 Minute Service Area	52,491	68,977	+31%
10 Minute Service Area	83,560	119,194	+43%
15 Minute Service Area	99,692	144,070	+45%

Table 3: Breakdown of the number of residences found within various walking distances of a bus stop

The results show a dramatic increase in accessible residential structures, highlighting the importance of the connectivity and functionality of the sidewalk networks in Austin. At 5 minutes, a complete sidewalk network sees a 31% increase in accessibility.

A 43% increase in accessible residential structures is seen at 10 minutes. At the 15-minute walk time, almost 50% more residential buildings are accessible with a complete sidewalk network. Table 4 details potential increases in accessibility through a complete sidewalk network for different residential types.

		Number of Residences Accessible Within 5 Minutes of a Bus Stop			Number of Residences Accessible Within 10 Minutes of a Bus Stop			Number of Residences Accessible Within 15 Minutes of a Bus Stop		
	COA Totals	Current Sidewalk	Complete Sidewalk	Percent Change	Current Sidewalk	Complete Sidewalk	Percent Change	Current Sidewalk	Complete Sidewalk	Percent Change
Apartments	19,759	6,678	8,755	+31%	8,419	11,964	+42%	9,285	13,657	+47%
Large Lot Single Family	145	2	2	0%	5	11	+120%	12	22	+83%
Mixed Use	132	114	119	+4%	114	120	+5%	117	120	+3%
Mobile Home	4,558	714	1,150	+61%	1,154	2,241	+94%	1,402	3,041	+117%
Single Family	185,845	44,983	58,951	+31%	73,868	104,858	+42%	88,876	127,230	+43%

Table 4: Sidewalk network comparisons at identical walk times

As shown in Table 4, a complete sidewalk network would produce an additional 31% of apartment buildings within a 5-minute walking time from bus stops in Austin. The same can be said for single family residences, which see a 31% increase in homes that are within a 5-minute walking time from bus stops. Mobile homes would experience the greatest benefit from a complete sidewalk network. A 61% increase in accessible mobile homes is seen at a 5-minute walking time. This suggests that mobile homes are particularly negatively affected by the current sidewalk network. They experience poor connectivity to bus stops through the sidewalk network.

A complete sidewalk network also drastically increases the accessibility of all residence types that are within a ten-minute walk from bus stops. Single family homes and apartments again see the same percentage increase, with a 42% increase under a complete sidewalk network. Mobile homes would also experience much greater connectivity. Accessible mobile homes within a ten-minute walk from bus stops almost double under the complete sidewalk model. Large lot single family residents experience the largest percentage growth under the complete sidewalk scenario at 120% growth.

The same patterns are observed for 15-minute walk times. Apartments see a large growth in accessibility when comparing the existing sidewalk network and the complete network. A 47% increase in apartments accessible within a 15-minute walk is seen. Large lot single family homes experience a large increase in accessibility while mobile homes experience the largest percentage increase. Between all residential types, the results suggest that mobile homes would benefit the most from an expansion of the current sidewalk network to a comprehensive, connected, and functional network. Alternatively, it could be that the current sidewalk is least present in areas where mobile homes exist. This would present an issue of equity in accessibility to bus stops for people living in mobile homes.

Neighborhood-Level Results

Tier 2 results focus on analysis at the neighborhood level. Analysis at this level focuses on three main measures: missing sidewalk, number of bus stops, and accessibility to residential buildings. An overlay of the most and least accessible neighborhoods is placed on several maps. These neighborhoods were found through the following: the percent of accessible residential buildings for each walking time of 5, 10, and 15 minutes was averaged to get a composite average score. The "most accessible neighborhoods" (MANS) consist of the top ten percent of neighborhoods that have the highest composite score of accessible residences. The "least accessible neighborhoods" (LANS) consist of the bottom ten percent of neighborhoods that have the lowest composite score of accessible residences. Neighborhoods that contain no bus stops are not included in the least accessible neighborhoods classification. This step is taken in order to compare between neighborhoods that contain at least one bus stop. This step was only taken in examining accessibility; all neighborhoods are otherwise included in this section's analysis. First, we examine the percent of missing sidewalk per neighborhood, then the number of bus stops per neighborhood, then levels of accessibility from bus stops to residential structures per neighborhood.

Neighborhood-level sidewalk analysis

Large variability exists in regards to the percentage of missing sidewalk per neighborhood. The definition for missing sidewalk in this analysis includes missing sidewalk and also sidewalk that currently exists but is "functionally deficient" as per the City of Austin Sidewalks Conditions data. The highest percentage of missing sidewalk for one neighborhood is 92%; the lowest percentage of missing sidewalk for one neighborhood is 9%. All neighborhoods in the study are missing portions of sidewalk.

Figure 5 shows the percentage of missing sidewalk per neighborhood, with overlays showing the MANS and LANS in the study area.

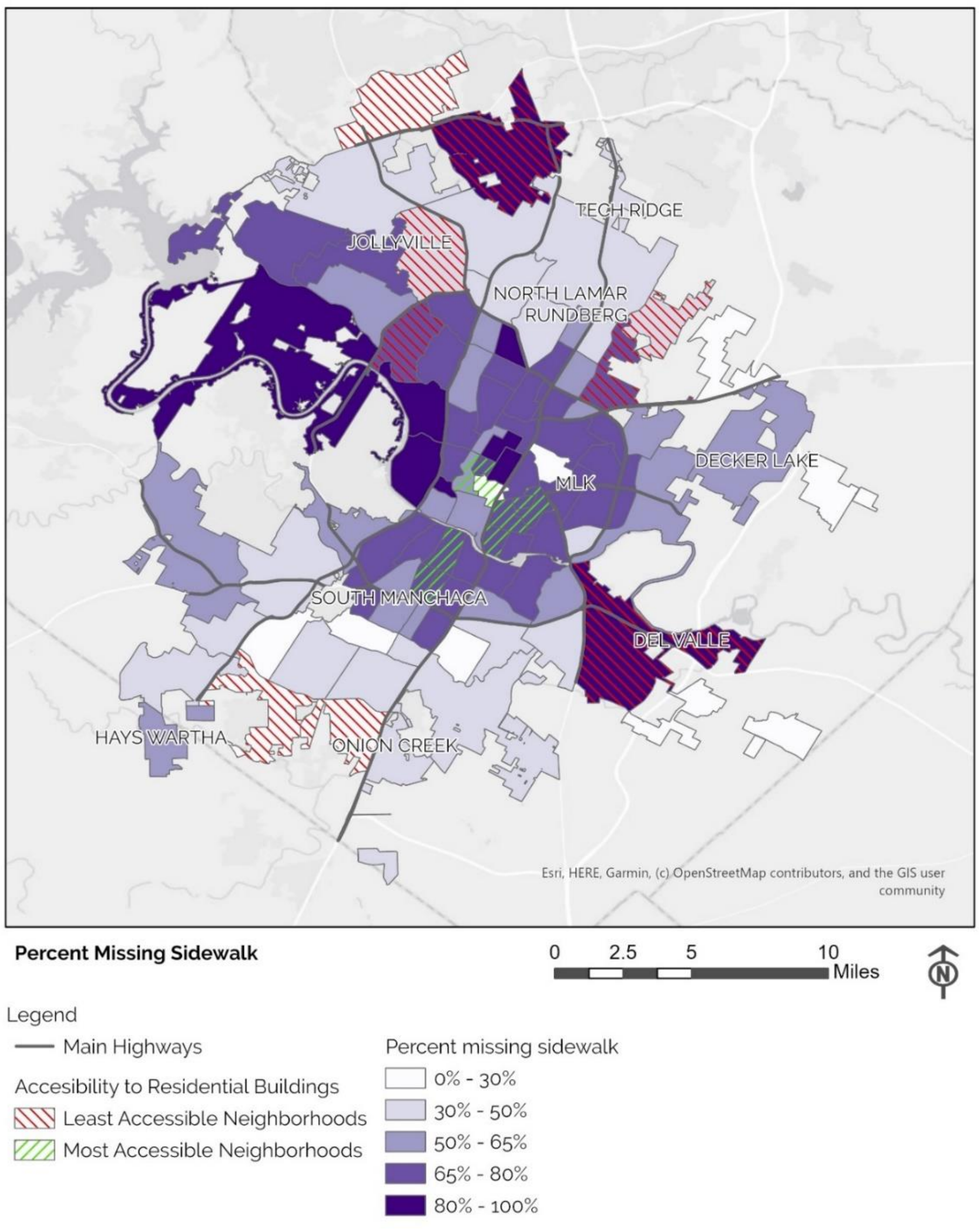

Figure 5: Percentage of missing sidewalk per neighborhood

Some patterns exist at the neighborhood level when looking at the geography of percentage of missing sidewalk. Clusters of neighborhoods with a high percentage of missing sidewalks can be found throughout the study area (Figure 5). Austin's inner loop appears to be missing more sidewalk than the city outskirts, with some exceptions. The Bergstrom neighborhood, home of Austin Bergstrom's international airport, is located on the city outskirts and has a high degree of missing sidewalks. The neighborhood adjacent to Bergstrom, Del Valle, is also missing the vast majority of its sidewalk network. The Robinson Ranch neighborhood, located in Austin's northern periphery, is among the neighborhoods with the worst missing sidewalk numbers. Bergstrom, Del Valle, and Robinson Ranch are also LANS. There is also a concentration of missing sidewalk in Austin's central neighborhoods. Slightly north of the University of Texas at Austin are the neighborhoods Hyde Park and Hancock, two neighborhoods with an especially high percentage of missing sidewalk within the inner loop. Another concentration of neighborhoods with a high percentage of missing sidewalk is found towards the west side of Austin. West Austin, Highland Park, Mansfield - River Place, and Davenport Lake.

Southern Austin has a cluster of neighborhoods with the smallest percentages of missing sidewalk. Among these neighborhoods are Brodie Lane, Garrison Park, Franklin Park, Slaughter Creek, and South Brodie. Located more centrally are the University of Texas neighborhood and the Mueller neighborhood which are also among the neighborhoods missing the least amount of sidewalk in the study area. Although these neighborhoods are among those with the least percentage of missing sidewalk, they are still missing about a quarter of their sidewalk network – and interestingly, Slaughter Creek and South Brodie are LANS.

A considerable number of neighborhoods are missing more than half of their sidewalk. Of the 103 neighborhoods in this study, 70 are missing more than half of their sidewalk network. Table 5 shows the neighborhoods with the most and least percent of missing sidewalk.

Neighborhood	Total Residences	Average Percent Accessible	Bus Stops Per Square Mile	Percent Sidewalk Missing
Old Enfield	527	38%	24	92%
Highland Park	1,723	14%	4	89%
Bergstrom	22	0%	1	88%
West Austin Ng	3,925	22%	9	86%
Davenport Lake Austin	1,043	0%	0	84%
Hyde Park	2,263	63%	73	84%
Robinson Ranch	7	0%	0	84%
Wooten	1,392	49%	46	83%
Del Valle	982	7%	1	83%
Hancock	1,557	68%	64	81%
Average (NLAPMS)		**26%**	**22**	**85%**
Garrison Park	3,626	57%	39	30%
Brodie Lane	3,516	42%	8	27%
Franklin Park	3,293	61%	16	27%
Mueller	609	12%	33	26%
Del Valle East	1,532	50%	2	25%
UT	16	98%	92	25%
Harris Branch	1,308	0%	0	23%
Slaughter Creek	3,226	7%	7	22%
South Brodie	4,965	7%	2	16%
Avery Ranch--Lakeline	3,386	1%	3	9%
Average (NLOPMS)		**34%**	**20**	**23%**

Table 5: Neighborhoods with the most and least amounts of missing sidewalk (percentage)

The percentage of missing sidewalk of the neighborhoods in Table 5 can be compared against the number of bus stops in each neighborhood and the average percent of accessible residences. To start off, there is a massive difference between the percentage of missing sidewalk of the Neighborhoods with the Largest Percent of Missing Sidewalks

(NLAPMS) and Neighborhoods with the Lowest Percentages of Missing Sidewalk (NLOPMS). The average percent of missing sidewalks of the NLAPMS is 85%; the NLOPMS have an average of 23%. NLAPMS have an average of 22 bus stops per square mile while NLOPMS have an average of 20. Despite the drastically lower percentage of missing sidewalk, there is not a very large difference in the average percent of accessible residences. NLOPMS should theoretically have much more accessibility because of the higher number of bus stops and existing sidewalk. However, NLOPMS have an average accessibility of 34% and NLAPMS have an average accessibility of 26%.

Neighborhood-level bus stop analysis

Because the percentage of accessible residences per neighborhood is being used as a gauge for pedestrian accessibility through the existing Austin sidewalk network, it is also important to analyze the number of bus stops found in the neighborhoods. This is because the quantity of bus stops and their location relative to residential buildings will result in higher accessibility. There exists a large range of stops per square mile at the neighborhood level. Nine out of the 103 neighborhoods in the study area have no bus stops found within their boundaries. The largest number for bus stops per square mile is 113 and is held by Chestnut. There are nine neighborhoods with a bus stops per square mile measure of 0.

Figure 6 shows the number of CapMetro bus stops per square mile for each neighborhood. This data is overlaid with MANS and LANS to visually study any relationships between bus stop quantities and residential accessibility. The mapping of bus stops per square miles at the neighborhood level produces distinct spatial patterns which can be seen in Figure 6. The neighborhoods with the highest number of bus stops per square mile are found in Austin's urban core – areas like Central East Austin, Rosewood, Chestnut, UT, North University, Hyde Park, and Triangle State. The density of bus stops per square mile decreases moving further away from the central area. This follows the heat map from Figure 4, which shows that the highest density of bus stops is found towards Austin's core. The decreasing amount of bus stops per square mile towards Austin's periphery can also be partially attributed to the increasing size of neighborhoods. The areas of neighborhoods in Austin's core are much smaller than those on the city's outskirts.

The spatial pattern described above closely resembles the pattern found for the neighborhoods that are most accessible. The most accessible neighborhoods (MANS), shown in a green hatch in Figure 6, are all located towards the city center. There is overlap between the MANS and the neighborhoods with the highest number of bus stops per square mile. Six out of the ten MANS are also neighborhoods with the highest number of bus stops per square mile. Central East Austin, Dawson, Chestnut, Rosewood, UT, and North University are MANS and are among the neighborhoods with the highest bus stops per square mile.

The least accessible neighborhoods (LANS) are all found in the study area periphery, much like the neighborhoods with the lowest number of bus stops per square mile. Almost all of the LANS (9 out of 10) are also neighborhoods with the smallest amount of bus stops per square mile, excluding neighborhoods with 0 bus stops. These neighborhoods include: South Brodie, Del Valle, Slaughter Creek, Bull Creek, Jollyville, Avery Ranch - Lakeline, Samsung - Pioneer Crossing, Bergstrom, and Robinson Ranch. The spatial relationship between MANS, LANS, and the level of bus stops per square mile can be observed in Figure 6.

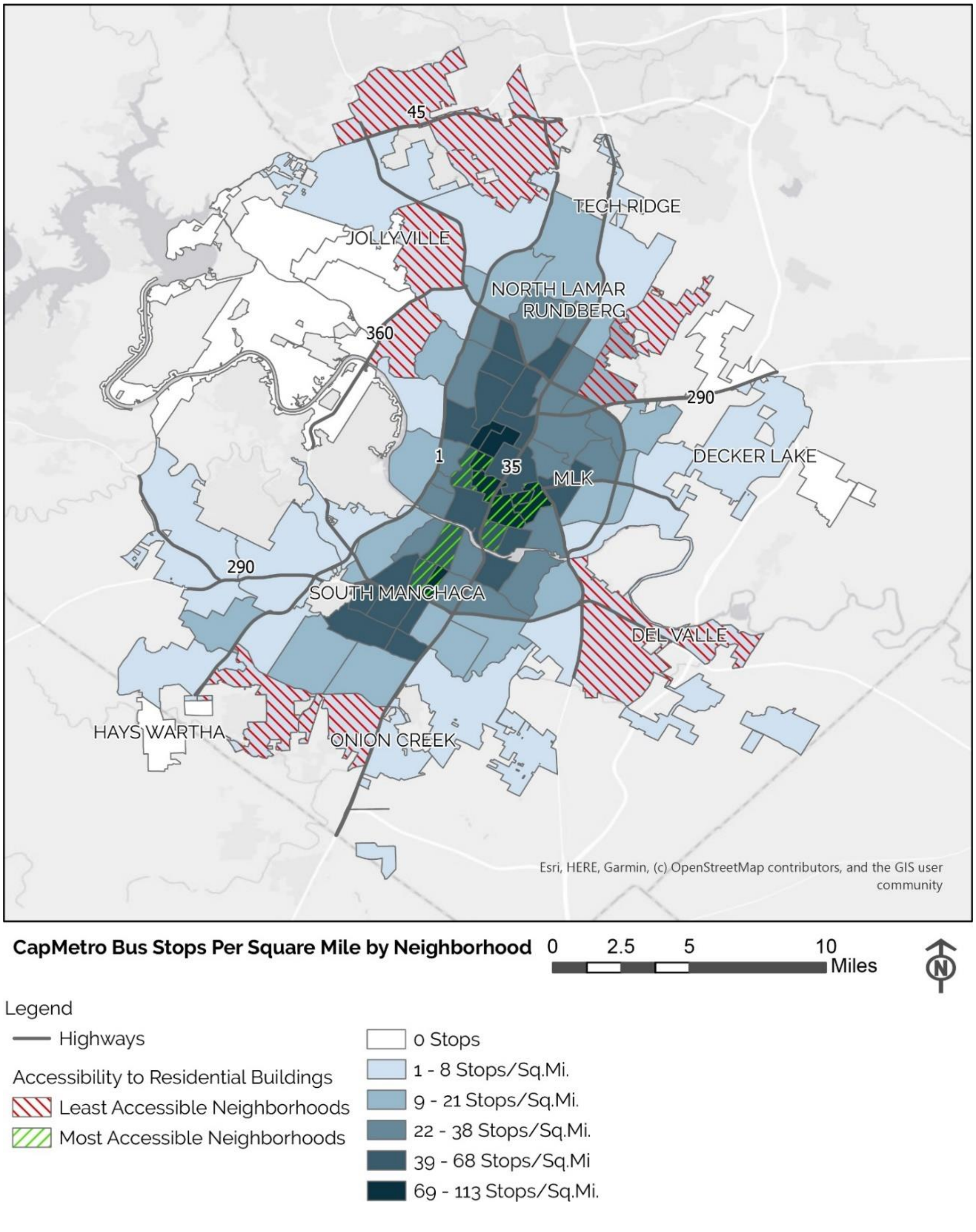

Figure 6: CapMetro Bus Stops per Square Mile per Neighborhood

Table 6 shows the neighborhoods with the most and least number of bus stops per square mile. Nine of the bottom ten neighborhoods have no bus stops. The bottom ten neighborhoods will be referred to as "Bus Stop Poor" (BSP) neighborhoods; the top ten neighborhoods will be referred to as "Bus Stop Rich" (BSR) neighborhoods.

Neighborhood	Total Residences	Average Percent Accessible	Bus Stops Per Square Mile	Percent Sidewalk Missing
Chestnut	743	85%	113	76%
North University	831	97%	101	77%
UT	16	98%	92	25%
Rosewood	1,378	77%	88	78%
Triangle State	33	65%	84	57%
Dawson	816	76%	79	66%
Hyde Park	2,263	63%	73	84%
Central East Austin	1,606	79%	68	76%
West Congress	692	50%	65	64%
Hancock	1,557	68%	64	81%
Average (BSR)		**76%**	**82.6**	**68%**
Decker Lake	8	25%	1	63%
Robinson Ranch	7	0%	0	84%
Davenport Lake Austin	1,043	0%	0	84%
Mansfield--River Place	1,491	0%	0	80%
Spicewood	118	0%	0	79%
Four Points	675	0%	0	70%
Jester	1,527	0%	0	57%
Harris Branch	1,308	0%	0	23%
Hays Wartha	0	-	0	57%
Whisper Valley	0	-	0	-
Average (BSP)		**3%**	**0**	**66%**

Table 6: Neighborhoods with the most and least number of bus stops per square mile

A large difference is observed in bus stops per square mile between BSP and BSR neighborhoods. BSP neighborhoods show an average of 0 bus stops per square mile. BSR neighborhoods show an average of 82.6 bus stops per square mile. BSP and BSR neighborhoods have almost similar results in regards to the percentage of missing sidewalk. BSP neighborhoods have a 66% average of sidewalk missing. BSR neighborhoods are slightly worse at 68% average of sidewalk missing. Given that the percentages of missing sidewalk between BSP and BSR neighborhoods are almost identical, it could be posited that their accessibilities would also be similar. However, a large difference is present between BSP and BSR neighborhoods in regards to residential accessibility. The average percent of accessibility to residential buildings for BSR neighborhoods is 76%. The same measure is only 3% for BSP neighborhoods. Such a difference can be partially explained because of the lack of bus stops in BSP neighborhoods: if there are no bus stops, there is no measure of accessibility from the bus stops. Also important to consider is the placement of the bus stops. Bus stops placed far away from residences would not show accessibility no matter the number of stops. This factor becomes more important when calculating accessibility for increasingly larger-area neighborhoods. Figure 6 shows some spatial relationship between bus stops and accessibility. Table 6 supports this spatial relationship by showing that bus stop density is essential for residential accessibility.

Neighborhood-level residential accessibility analysis

This analysis looks into bus stop accessibility to residential areas through Austin's existing sidewalk network. Figure 7 shows the percent of residential buildings accessible per neighborhood for three different walking times.

At 5 minutes, the neighborhoods with the highest percentage of residential buildings within walking distance from bus stops are found more centrally in the City of

Austin. The neighborhoods with the lowest percentage of residential buildings within walking distance from bus stops are found on the COA outskirts. Out of all the 103 neighborhoods, 44 have a residential accessibility of 0% - 20%. Four neighborhoods are in the highest accessibility cluster. These neighborhoods are: East Cesar Chavez, Chestnut, UT, and North University.

At 10 minutes, thirteen neighborhoods are in the highest accesibility cluster. These neighborhoods are: Cesar Chavez, Chestnut, UT, and North University, West University, Hancock, Hyde Park, Rosewood, Bouldin Creek, Central East Austin, Dawson, Galindo, and MLK. The neighborhoods with the highest accessibility are still found towards Austin's central areas. Some peripheral neighborhoods show improved levels of accessibility. Higher levels of accessibility are seen across the entire study area compared to the 5-minute walking time accessibility.

At 15 minutes, six additional neighborhoods join the highest accessibility cluster: Old West Austin, Franklin Park, Garrison Park, Bluff Springs, Sweetbriar, and North Lamar Rundberg. Given such a long walking time, accessibility is greatly improved over the 5-minute walking time accessibility.

The percentage of accessible residential buildings for the three walking times is averaged to get a composite average score per neighborhood. Figure 8 shows the averaged neighborhood accessibility score. The composite score closely follows patterns observed throughout the 5, 10, and 15-minute accessibility maps from Figure 7. Neighborhoods that are centrally located hold the highest accessibility to residential structures from bus stops. Neighborhoods found towards the study area periphery have less accessibility to residential structures.

Figure 7: Percentage of Residential Structures accessible within various walking times. From left to right: 5-minute walking time, 10-minute walking time, 15-minute walking time

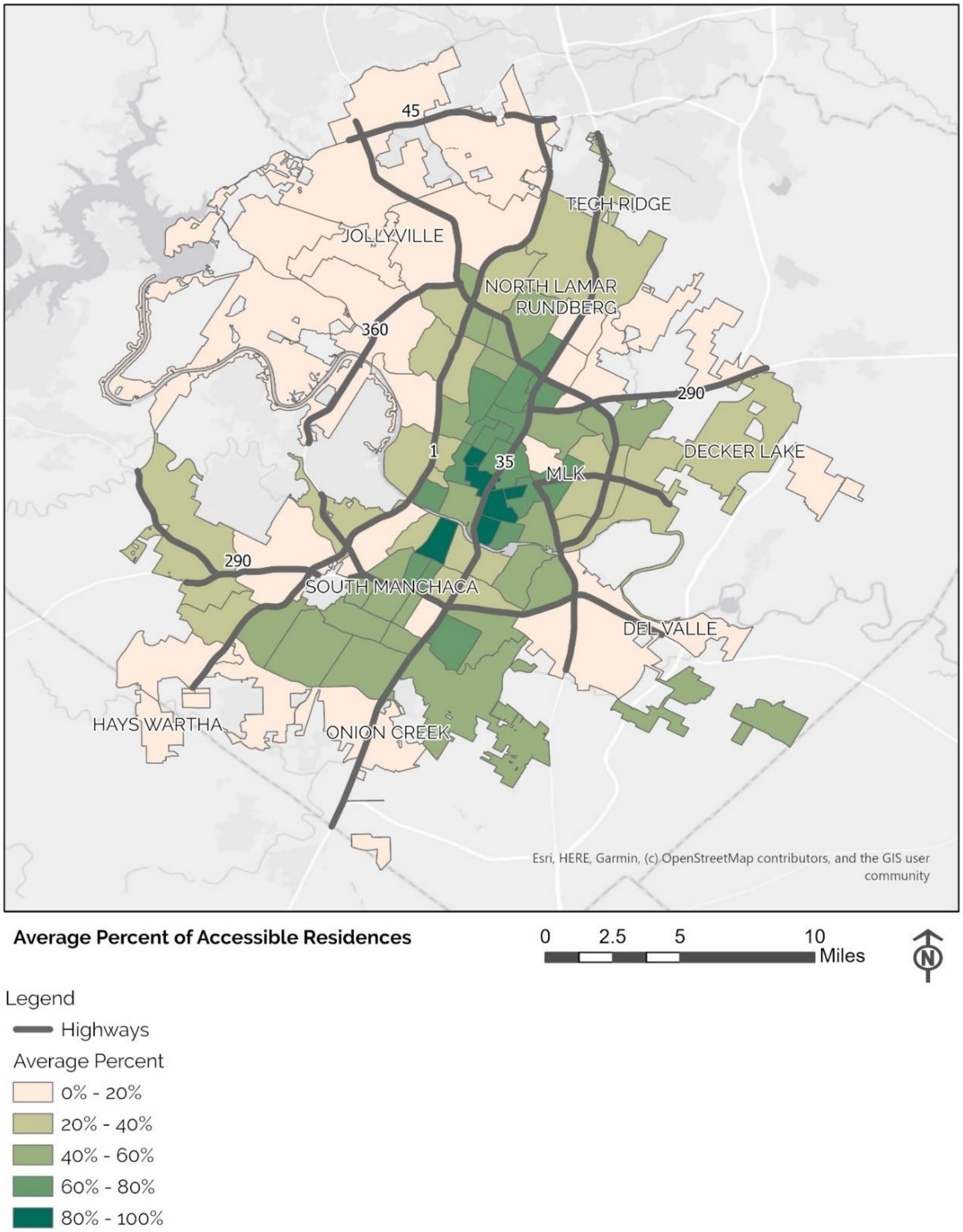

Figure 8: Average Percentage of accessible residences per neighborhood

Table 7 shows the neighborhoods with the most accessibility to residential structures (MANS) and those with the least accessibility (LANS). The average accessibility for MANS is 84%, a tremendous difference to the average LANS accessibility of 4%. This disparity is carried over to the measure of average bus stops per square mile. While MANS have a 77.5 average bus stops per square mile, LANS have an average of 3 bus stops per square mile. Interestingly, MANS have a much higher average of missing sidewalk than LANS. MANS experience 68% average missing sidewalks and LANS experience 51% average of missing sidewalks. LANS have a more comprehensive sidewalk network but they have a much lower accessibility to residential buildings from bus stops. South Brodie and Slaughter creek are two of the neighborhoods with the least amount of missing sidewalk, yet they exhibit very poor accessibility to residential buildings. This could be explained due to the low amount of bus stops found within each neighborhood. Table 7 shows that South Brodie only has 2 bus stops per square mile while Slaughter Creek has 7. If we compare this to North University and East Cesar Chavez, both of which have many more bus stops per square mile, we can see that they have much higher accessibility despite their high percentages of missing sidewalks. These results suggest that the availability of bus stops play a larger role in residential accessibility than does the availability of sidewalk.

Further indication that bus stop quantity is related to residential accessibility is that six out of the ten MANS are bus stop rich neighborhoods. They are the following neighborhoods: Chestnut, North University, UT, Dawson, Rosewood, and Central East Austin. The percentage of existing sidewalk is not as strong of a factor as previously thought. UT is the only MANS that is also one of the neighborhoods with the least percentage of missing sidewalk. The UT neighborhood is the only neighborhood which is grouped into the top cluster of all three observed measures.

Of the LAPS, Robinson Ranch is the only neighborhood that is also a bus stop poor neighborhood. Bergstrom, Robinson Ranch, Del Valle all LANS that are also NLAPMS. Robinson Ranch is in the worst performing cluster for percent of existing sidewalks, bus stop density, and residential accessibility.

Neighborhood	Total Residences	Average Percent Accessible	Bus Stops Per Square Mile	Percent Missing Sidewalk
UT	16	98%	92	25%
North University	831	97%	101	77%
East Cesar Chavez	1,111	91%	56	74%
Chestnut	743	85%	113	76%
Bouldin Creek	1,962	84%	58	76%
Central East Austin	1,606	79%	68	76%
Rosewood	1,378	77%	88	78%
Galindo	1,062	76%	57	69%
Dawson	816	76%	79	66%
West University	996	75%	64	64%
Average (MANS)		**84%**	**77.5**	**68%**
South Brodie	4,965	7%	2	16%
Del Valle	982	7%	1	83%
Walnut Creek--Pioneer Hill	499	7%	9	67%
Slaughter Creek	3,226	7%	7	22%
Bull Creek	2,791	7%	1	70%
Jollyville	5,557	4%	4	46%
Avery Ranch--Lakeline	3,386	1%	3	9%
Samsung--Pioneer Crossing	1,608	1%	1	30%
Bergstrom	22	0%	1	88%
Robinson Ranch	7	0%	0	84%
Average (LANS)		**4%**	**3.0**	**51%**

Table 7: Most and least accessible neighborhoods

Bus Stop-level Results

This section focuses on the analysis of sidewalk conditions at the bus stop level. There are a total of 2,273 bus stops found in the study area. The condition of the sidewalk adjacent to each bus stop is explored. There are three categories of sidewalk conditions: existing functionally acceptable, existing functionally deficient, and missing. Existing functionally acceptable sidewalk is defined as sidewalk that currently exists and is in functionally acceptable conditions as per the City of Austin Sidewalk Conditions dataset. Existing functionally acceptable sidewalk is defined as sidewalk that currently exists and is in functionally deficient condition as per the City of Austin Sidewalk Conditions dataset. Missing sidewalk is sidewalk that is marked as missing as per the City of Austin sidewalks GIS layer. Figure 9 shows the distribution of bus stops by their sidewalk condition.

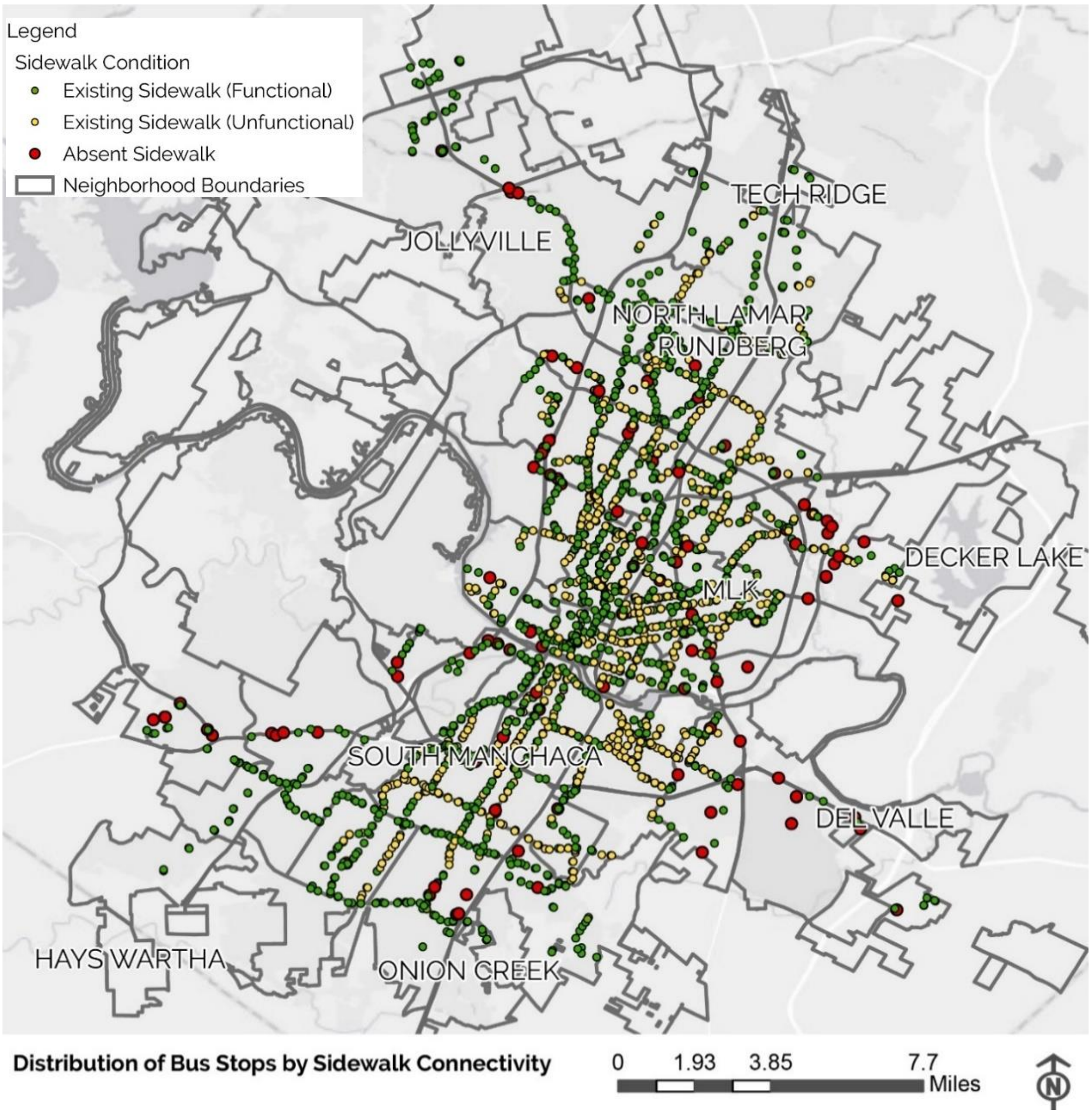

Figure 9: Bus stops by sidewalk condition

There are a total of 1,338 bus stops that are connected to existing, functionally accessible sidewalk. Fifty nine percent of bus stops are connected to sidewalks in this condition. Figure 10 below is an example of a bus stop that is well connected to quality sidewalk. The bus stop is accessible from either side because of the available sidewalk.

Figure 10: Bus stop with existing sidewalk

There is a total of 828 bus stops (36%) that are found next to existing but functionally deficient sidewalks. Figure 11 shows an example of a bus stops connected by existing, functionally deficient sidewalk. The sidewalk is present and connects on both side of the bus stop, however, the sidewalk has utility poles in the middle of the walkway. The poles would be a physical obstacle to someone who is trying to access the bus stop.

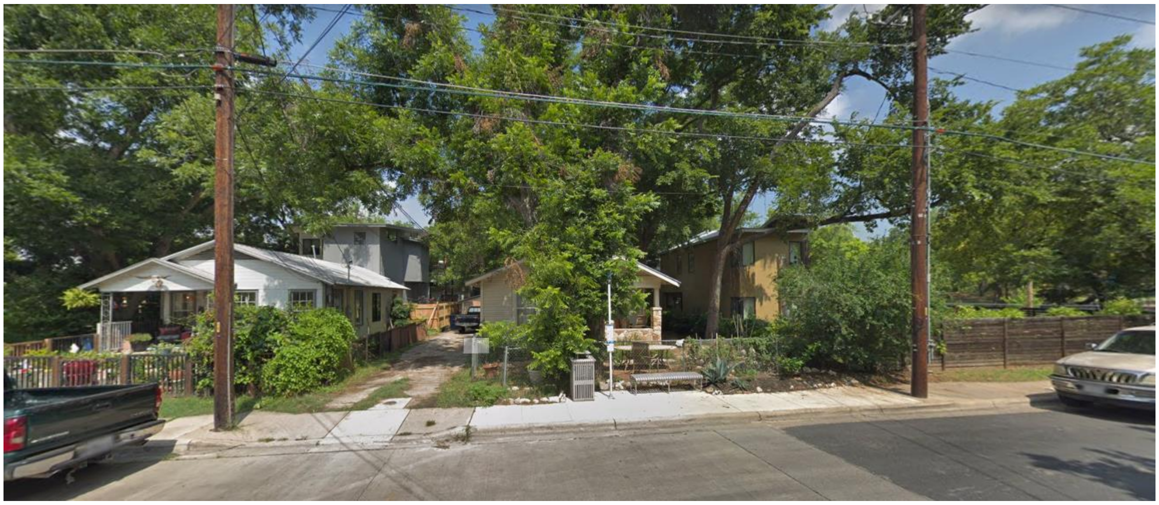

Figure 11: Bus stop with existing, functionally deficient sidewalk

There are 107 bus stops (5%) that are not connected to sidewalk. These bus stops exist as disconnected parcels of sidewalk but they are not accessible by connecting sidewalk. Figure 12, Figure 13, and Figure 14 are examples of bus stops found with no connecting sidewalk.

Figure 12: Bus stop with no adjacent sidewalk, example 1

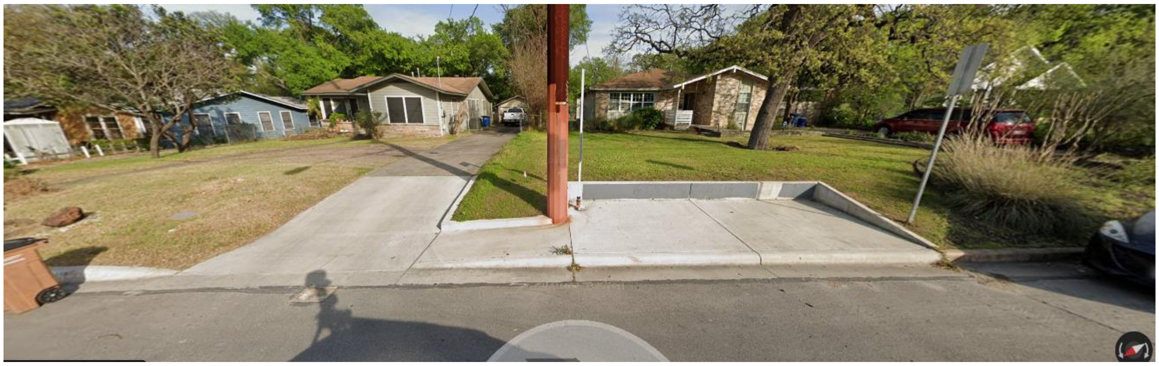

Figure 13: Bus stop with no adjacent sidewalk, example 2

Figure 14: Bus stop with no adjacent sidewalk, example 3

CONCLUSION

The aim of this study was to examine neighborhood accessibility to bus stops using a GIS network analysis-based approach in the City of Austin. This was important because Austin is currently missing more than half of its sidewalk network and a well-connected sidewalk network is necessary for transit use. Transit use would help the City of Austin reach city goals for sustainability and health. This study uses City of Austin sidewalk data to model the real-life conditions a pedestrian would encounter while walking on Austin sidewalks.

It was seen that the best-connected neighborhoods are the ones with a high availability of bus stops. The high number of bus stops found within a neighborhood is what was most associated with neighborhood connectivity. In this study, it was also found that neighborhoods that have to highest accessibility to bus stops are mostly found towards Austin's city center while neighborhoods that have the poorest connection to bus stops are found towards Austin's suburban areas. Neighborhoods containing the highest number of bus stops are also found towards the city center. Neighborhoods with the highest amount of missing sidewalk are found in a few clusters throughout the city boundary.

Our findings that better-connected neighborhoods have higher access to bus stops falls in line with other research. It is a common finding that more walkable areas are often found in inner-city or downtown areas (Jeffrey et al., 2019). Gunn et al found that highly walkable areas are often located close to the Central Business district in Melbourne and had built environment features that are more pedestrian friendly (2017). Pedestrian friendly features include higher street connectivity (Gunn et al., 2017). McCormack et al found that highly walkable neighborhoods were most likely found in the inner-city area and had highly connected pedestrian network with high access to sidewalks, and a high number of bus stops (2012). McCormack also found that less walkable neighborhoods are found in middle and outer neighborhoods and had less sidewalk connectivity, fewer sidewalks, and fewer bus stops (2012).

More than half of the bus stops in Austin are found adjacent to existing, fully functional sidewalks. About a third of stops are found with existing yet functionally deficient sidewalks. Only about 5% of bus stops are not connected to the sidewalk network. Overall, the majority of bus stops have at least some form of existing sidewalk connecting it to the rest of the network. When considering that the City of Austin is missing about half of its sidewalk, these results are encouraging.

It was also seen that a full build out of the sidewalk network would increase the amount of residential buildings that are accessible from Austin's bus stops. The City of Austin sidewalk master plan highlights the importance of completing the sidewalk network within a quarter mile distance of all bus stops. The results from this report support that sidewalks found within close distances of bus stops are important to build. An increase of sidewalk presence increased the amount of residential buildings that are accessible from Austin bus stops. All residential building types would see substantially improved accessibility, but mobile homes would see the most improvement.

This research is best positioned to inform the identification of neighborhoods that could benefit most from an improvement of sidewalk infrastructure and of bus services. The results could be used to guide sidewalk development or identify areas with the strongest potential to benefit from improved bus service. Identification of such neighborhoods is an important first step towards developing an improved pedestrian network that better connects with transit, promotes ridership, and ultimately achieves sustainability, health, and transportation-related goals set out by the city.

Findings here can help improve walkability and accessibility to bus stops in City of Austin neighborhoods. As the City of Austin continues to grow, which it absolutely will, it should consider its broader transportation strategies. The City has already taken a strong step with Project Connect. If it continues to maximize public transportation use, along with strong sidewalk infrastructure and bus stop density, it can future-proof the demands of the city.

LIMITATIONS

The sidewalk network could be better modeled if it contained connectivity across blocks. Future sidewalk data could include connections between blocks represented as cross walks at road intersections. The buffers used in making the sidewalk network in this study inherently modeled sidewalk that does not currently exist, possibly creating sidewalk continuity in the sidewalk network that does not exist. While I am aware that my workaround is not a perfect solution, it is the approach closest to modeling the real conditions found in the city.

APPENDICES

Appendix A: Table of all study area neighborhood attributes organized by neighborhood accessibility

Neighborhood	Total Residential Structures	Average Percent Accessible	Number of Bus Stops	Percent of Sidewalk Missing
UT	16	98%	70	25%
North University	831	97%	37	77%
East Cesar Chavez	1,111	91%	38	74%
Chestnut	743	85%	32	76%
Bouldin Creek	1,962	84%	69	76%
Central East Austin	1,606	79%	66	76%
Rosewood	1,378	77%	79	78%
Galindo	1,062	76%	39	69%
Dawson	816	76%	39	66%
West University	996	75%	47	64%
Hancock	1,557	68%	54	81%
Holly	1,319	66%	33	72%
Brentwood	2,969	66%	83	67%
St. Johns	1,042	65%	39	67%
Triangle State	33	65%	38	57%
MLK	1,444	64%	90	77%
Highland	1,662	63%	62	71%
Upper Boggy Creek	2,424	63%	62	79%
Hyde Park	2,263	63%	55	84%
Georgian Acres	1,264	63%	43	68%
North Loop	1,886	62%	40	79%
Franklin Park	3,293	61%	35	27%
Old West Austin	1,335	60%	24	55%
Westgate	1,033	58%	53	75%
North Lamar Rundberg	4,572	57%	100	47%
Bluff Springs	5,608	57%	58	31%
Govalle	1,512	57%	55	76%
Garrison Park	3,626	57%	76	30%
LBJ	552	57%	27	60%
Sweetbriar	1,192	56%	41	44%
Cherry Creek	7,025	56%	79	38%

Montopolis	2,620	55%	42	53%
Windsor Park	3,742	52%	76	76%
Gateway	101	51%	13	46%
South Manchaca	2,575	51%	64	65%
Rosedale	2,816	50%	57	74%
Del Valle East	1,532	50%	11	25%
West Congress	692	50%	38	64%
Wooten	1,392	49%	44	83%
Downtown	281	48%	91	52%
Crestview	2,111	45%	44	76%
Pleasant Valley	975	44%	72	76%
McKinney	1,144	44%	24	41%
Dittmar—Slaughter	5,313	43%	68	34%
University Hills	1,420	42%	24	79%
Brodie Lane	3,516	42%	22	27%
North Shoal Creek	958	40%	25	55%
South Lamar	1,592	39%	53	60%
South River City	2,124	39%	33	74%
Parker Lane	1,236	38%	50	56%
Old Enfield	527	38%	8	92%
Johnston Terrace	564	36%	5	49%
Gracy Woods	7,633	34%	72	41%
Riverside	970	34%	52	74%
North Burnet	272	34%	53	45%
Village At Western Oaks	3,572	33%	26	31%
MLK-183	2,480	33%	61	74%
Zilker	2,175	33%	33	70%
Northwest Hills	2,542	32%	28	69%
Allandale	2,515	31%	54	61%
Pecan Springs-Springdale	1,467	30%	46	75%
Rogers Hill	2,844	29%	30	51%
Barton Creek Mall	1,529	29%	18	54%
St. Edwards	475	28%	25	66%
West Oak Hill	4,782	27%	25	61%
Windsor Road	1,660	26%	23	77%
Decker Lake	8	25%	5	63%
Tech Ridge	3,719	24%	37	42%
Westover Hills	2,184	24%	13	70%
West Austin Ng	3,925	22%	28	86%
Coronado Hills	387	20%	17	60%

North Lamar	965	19%	31	53%
Circle C South	4,647	17%	4	42%
Windsor Hills	1,759	15%	14	47%
McNeil	6,732	14%	33	46%
Highland Park	1,723	14%	12	89%
Pond Springs	3,180	14%	11	36%
East Oak Hill	3,735	13%	26	47%
Mueller	609	12%	39	26%
East Congress	947	11%	18	66%
Barton Hills	1,960	11%	26	73%
Anderson Mill	8,333	11%	15	39%
Onion Creek	2,463	10%	6	36%
Southeast	879	9%	15	47%
Heritage Hills	952	9%	30	57%
South Brodie	4,965	7%	10	16%
Del Valle	982	7%	6	83%
Walnut Creek—Pioneer Hill	499	7%	28	67%
Slaughter Creek	3,226	7%	26	22%
Bull Creek	2,791	7%	5	70%
Jollyville	5,557	4%	25	46%
Avery Ranch-Lakeline	3,386	1%	18	9%
Samsung-Pioneer Crossing	1,608	1%	2	30%
Bergstrom	22	0%	10	88%
Davenport Lake Austin	1,043	0%	0	84%
Four Points	675	0%	0	70%
Harris Branch	1,308	0%	0	23%
Hays Wartha	0	-	0	57%
Jester	1,527	0%	0	57%
Mansfield-River Place	1,491	0%	0	80%
Robinson Ranch	7	0%	3	84%
Spicewood	118	0%	0	79%
Whisper Valley	0	-	0	-

Appendix B: Table of accessible residential buildings within a 5-minute walk time per neighborhood by residential type

Neighborhood	Total Residential Structures	Accessible Residences	Apartments	Large Lot Single Family	Mixed Use	Mobile Homes	Single Family
Allandale	2,515	19%	41%	-	100%	-	18%
Anderson Mill	8,333	6%	4%	-	-	0%	6%
Avery Ranch--Lakeline	3,386	1%	0%	-	-	0%	1%
Barton Creek Mall	1,529	14%	0%	-	-	-	15%
Barton Hills	1,960	8%	20%	-	-	0%	5%
Bergstrom	22	0%	0%	0%	-	0%	-
Bluff Springs	5,608	42%	18%	0%	-	53%	43%
Bouldin Creek	1,962	71%	68%	-	-	-	71%
Brentwood	2,969	57%	68%	-	92%	-	56%
Brodie Lane	3,516	28%	1%	0%	-	50%	29%
Bull Creek	2,791	5%	29%	0%	-	0%	3%
Central East Austin	1,606	72%	93%	-	-	60%	70%
Cherry Creek	7,025	40%	45%	0%	-	41%	40%
Chestnut	743	80%	11%	-	-	100%	86%
Circle C South	4,647	6%	-	-	-	-	6%
Coronado Hills	387	12%	25%	-	-	0%	2%
Crestview	2,111	27%	31%	-	67%	-	27%
Davenport Lake Austin	1,043	0%	0%	-	-	-	0%
Dawson	816	62%	72%	-	100%	100%	60%
Decker Lake	8	0%	0%	-	-	-	0%
Del Valle	982	4%	0%	0%	-	4%	4%
Del Valle East	1,532	35%	-	0%	-	53%	35%
Dittmar--Slaughter	5,313	26%	76%	-	-	5%	26%
Downtown	281	31%	48%	-	100%	-	18%
East Cesar Chavez	1,111	85%	74%	-	-	-	86%
East Congress	947	7%	26%	-	-	16%	4%
East Oak Hill	3,735	4%	3%	0%	-	0%	5%
Four Points	675	0%	0%	-	-	-	0%
Franklin Park	3,293	41%	32%	-	-	11%	44%
Galindo	1,062	70%	82%	-	-	13%	74%

Garrison Park	3,626	42%	78%	-	-	27%	40%
Gateway	101	45%	45%	-	-	-	-
Georgian Acres	1,264	52%	21%	-	-	31%	64%
Govalle	1,512	43%	63%	-	-	25%	43%
Gracy Woods	7,633	19%	37%	0%	-	46%	17%
Hancock	1,557	55%	72%	-	-	-	54%
Harris Branch	1,308	0%	-	-	-	-	0%
Hays Wartha	-	-	-	-	-	-	-
Heritage Hills	952	2%	9%	-	-	0%	1%
Highland	1,662	48%	61%	-	-	-	47%
Highland Park	1,723	11%	6%	0%	-	-	12%
Holly	1,319	58%	85%	-	100%	25%	56%
Hyde Park	2,263	48%	90%	-	-	-	45%
Jester	1,527	0%	0%	0%	-	-	0%
Johnston Terrace	564	13%	0%	0%	-	59%	11%
Jollyville	5,557	1%	6%	-	-	0%	1%
LBJ	552	42%	13%	-	-	-	44%
Mansfield--River Place	1,491	0%	0%	0%	-	-	0%
McKinney	1,144	31%	54%	-	-	25%	30%
McNeil	6,732	6%	9%	-	-	0%	6%
MLK	1,444	52%	72%	-	-	17%	51%
MLK-183	2,480	27%	18%	-	-	26%	27%
Montopolis	2,620	39%	33%	-	-	15%	44%
North Burnet	272	20%	20%	-	0%	-	-
North Lamar	965	9%	23%	-	-	3%	7%
North Lamar Rundberg	4,572	40%	62%	-	-	8%	35%
North Loop	1,886	46%	49%	-	-	-	45%
North Shoal Creek	958	26%	29%	-	-	-	26%
North University	831	93%	94%	-	100%	-	93%
Northwest Hills	2,542	25%	64%	-	-	-	14%
Old Enfield	527	24%	51%	-	-	-	22%
Old West Austin	1,335	40%	53%	-	100%	-	37%
Onion Creek	2,463	4%	12%	0%	-	0%	3%
Parker Lane	1,236	30%	34%	-	-	8%	28%
Pecan Springs-Springdale	1,467	22%	40%	0%	-	-	21%
Pleasant Valley	975	39%	43%	-	-	-	21%
Pond Springs	3,180	6%	18%	-	-	0%	5%
Riverside	970	23%	37%	-	-	-	7%
Mueller	609	1%	100%	-	100%	-	1%
Robinson Ranch	7	0%	-	-	-	-	0%

Rogers Hill	2,844	24%	45%	29%	-	3%	29%
Rosedale	2,816	37%	69%	-	-	-	36%
Rosewood	1,378	66%	77%	-	-	20%	65%
Samsung--Pioneer Crossing	1,608	0%	0%	-	-	0%	0%
Slaughter Creek	3,226	5%	16%	0%	-	86%	3%
South Brodie	4,965	5%	88%	0%	-	28%	4%
South Lamar	1,592	27%	36%	-	100%	-	22%
South Manchaca	2,575	37%	85%	-	-	27%	35%
South River City	2,124	29%	42%	-	100%	-	27%
Southeast	879	7%	-	0%	-	19%	0%
Spicewood	118	0%	0%	-	-	-	0%
St. Edwards	475	19%	15%	-	100%	-	20%
St. Johns	1,042	52%	54%	-	-	67%	52%
Sweetbriar	1,192	38%	33%	-	-	49%	38%
Tech Ridge	3,719	18%	5%	0%	-	0%	20%
Triangle State	33	58%	33%	-	60%	-	-
University Hills	1,420	31%	20%	-	-	-	32%
Upper Boggy Creek	2,424	49%	76%	-	100%	-	49%
UT	16	94%	94%	-	-	-	-
Village At Western Oaks	3,572	21%	35%	-	-	100%	21%
Walnut Creek--Pioneer Hill	499	3%	9%	-	-	100%	0%
West Austin Ng	3,925	15%	43%	-	-	-	13%
West Congress	692	36%	69%	-	-	20%	32%
West Oak Hill	4,782	18%	3%	0%	-	0%	21%
West University	996	65%	76%	-	100%	-	58%
Westgate	1,033	42%	64%	-	-	-	38%
Westover Hills	2,184	14%	31%	-	-	-	8%
Whisper Valley	-	-	-	-	-	-	-
Windsor Hills	1,759	6%	30%	-	-	0%	4%
Windsor Park	3,742	38%	39%	-	-	33%	38%
Windsor Road	1,660	9%	70%	-	-	-	8%
Wooten	1,392	33%	38%	-	-	-	32%
Zilker	2,175	20%	52%	-	100%	-	16%

Appendix C: Table of residential accessibility of all neighborhoods by walking time

Neighborhood	Total Residential Structures	5 Minutes	10 Minutes	15 Minutes
Allandale	2,515	19%	30%	45%
Anderson Mill	8,333	6%	6%	20%
Avery Ranch--Lakeline	3,386	1%	1%	1%
Barton Creek Mall	1,529	14%	15%	57%
Barton Hills	1,960	8%	10%	16%
Bergstrom	22	0%	0%	0%
Bluff Springs	5,608	42%	43%	87%
Bouldin Creek	1,962	71%	97%	83%
Brentwood	2,969	57%	69%	72%
Brodie Lane	3,516	28%	29%	69%
Bull Creek	2,791	5%	7%	9%
Central East Austin	1,606	72%	85%	82%
Cherry Creek	7,025	40%	49%	79%
Chestnut	743	80%	82%	92%
Circle C South	4,647	6%	6%	37%
Coronado Hills	387	12%	27%	20%
Crestview	2,111	27%	56%	51%
Davenport Lake Austin	1,043	0%	0%	0%
Dawson	816	62%	82%	85%
Decker Lake	8	0%	25%	50%
Del Valle	982	4%	11%	6%
Del Valle East	1,532	35%	36%	79%
Dittmar--Slaughter	5,313	26%	27%	74%
Downtown	281	31%	64%	49%
East Cesar Chavez	1,111	85%	97%	91%
East Congress	947	7%	7%	20%
East Oak Hill	3,735	4%	6%	29%
Four Points	675	0%	0%	0%
Franklin Park	3,293	41%	52%	89%
Galindo	1,062	70%	81%	77%
Garrison Park	3,626	42%	41%	88%
Gateway	101	45%	45%	65%
Georgian Acres	1,264	52%	75%	61%

Govalle	1,512	43%	72%	57%
Gracy Woods	7,633	19%	23%	61%
Hancock	1,557	55%	94%	56%
Harris Branch	1,308	0%	0%	0%
Hays Wartha	-	0%	0%	0%
Heritage Hills	952	2%	20%	4%
Highland	1,662	48%	69%	73%
Highland Park	1,723	11%	12%	18%
Holly	1,319	58%	65%	77%
Hyde Park	2,263	48%	84%	56%
Jester	1,527	0%	0%	0%
Johnston Terrace	564	13%	17%	78%
Jollyville	5,557	1%	2%	8%
LBJ	552	42%	71%	58%
Mansfield--River Place	1,491	0%	0%	0%
McKinney	1,144	31%	37%	63%
McNeil	6,732	6%	7%	30%
MLK	1,444	52%	81%	59%
MLK-183	2,480	27%	38%	34%
Montopolis	2,620	39%	50%	74%
North Burnet	272	20%	43%	38%
North Lamar	965	9%	13%	36%
North Lamar Rundberg	4,572	40%	48%	84%
North Loop	1,886	46%	66%	74%
North Shoal Creek	958	26%	32%	62%
North University	831	93%	99%	99%
Northwest Hills	2,542	25%	29%	43%
Old Enfield	527	24%	50%	39%
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Onion Creek	2,463	4%	4%	22%
Parker Lane	1,236	30%	37%	48%
Pecan Springs-Springdale	1,467	22%	39%	28%
Pleasant Valley	975	39%	56%	39%
Pond Springs	3,180	6%	6%	30%
Riverside	970	23%	52%	27%
Mueller	609	1%	30%	4%
Robinson Ranch	7	0%	0%	0%
Rogers Hill	2,844	24%	27%	37%
Rosedale	2,816	37%	60%	54%
Rosewood	1,378	66%	90%	75%

Samsung--Pioneer Crossing	1,608	0%	1%	1%
Slaughter Creek	3,226	5%	6%	10%
South Brodie	4,965	5%	5%	13%
South Lamar	1,592	27%	44%	46%
South Manchaca	2,575	37%	49%	66%
South River City	2,124	29%	35%	53%
Southeast	879	7%	11%	8%
Spicewood	118	0%	0%	0%
St. Edwards	475	19%	22%	43%
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West University	996	65%	88%	72%
Westgate	1,033	42%	65%	67%
Westover Hills	2,184	14%	13%	43%
Windsor Hills	1,759	6%	13%	27%
Windsor Park	3,742	38%	54%	66%
Windsor Road	1,660	9%	13%	57%
Wooten	1,392	33%	57%	56%
Zilker	2,175	20%	28%	51%

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